2. RI/FS DATA COLLECTION ACTIVITIES

This chapter describes the data collection tasks and activities completed during the course of the RI/FS. All tasks were conducted in substantive accordance with procedures detailed in the *Landsburg Phase I Remedial Investigation/Feasibility Study Work Plan* (Golder 1992a). Interpretations of the data collected as part of these tasks are provided in subsequent chapters of this report.

The approach taken during the RI was to focus environmental sampling efforts on potential pathways of chemicals leaving the mine and not on wastes present within the mine itself. Investigation of wastes in the mine was limited due to physical constraints, dangers and difficulties associated with taking samples in the mine. It is important to note that the approach of focusing on pathways of chemicals leaving the mine specifically excludes characterization of the Cedar River. As such, data collection activities conducted under the RI included the following primary tasks:

- Task 3 - Air Monitoring
- Task 4 - Facility Environmental Assessment (Level 1)
- Task 5 - Private Well Survey
- Task 6 - Surface Water Sampling and Flow Monitoring From Portals #2 and #3
- Task 7 - Surface Soil Sampling
- Task 8 - Source Characterization in Rogers Trench (Geophysical Investigation)
- Task 9 - Monitoring Well Drilling and Installation
- Task 10 - Groundwater Sampling and Analysis
- Task 11 - Topographic Survey and Geodetic Control
- Task 12 - Ecological and Social Data
- Task 13 - Geologic Reconnaissance

All environmental sampling activities were conducted under an approved Quality Assurance Project Plan (QAPP) which was included as part of the Work Plan (Golder 1992a). Most field and data collection activities, described in this chapter, were completed during the period of October, 1993 to January, 1995.

2.1 Task 3 - Air Monitoring

Air monitoring was conducted in order to evaluate the potential for mobilization, via air dispersion, of potential volatile organic compounds from the subsidence trench. A total of three air monitoring surveys were conducted during the field investigation.

All three air monitoring events were conducted along the subsidence trench bottom in the northern half of the mine trench within the fenced and secured former disposal areas (Figure 2-1). Measurements were taken along the trench bottom at intervals of approximately 25 feet. Two readings using organic vapor instrumentation were taken at each monitoring location - one reading at breathing zone level, and one at a height of approximately 6 inches above the trench floor. The three air monitoring surveys were conducted on November 3, 1993; August 1, 1994; and January 16, 1995. Data collected during the three air monitoring events are discussed in Section 5.3.1 and summarized in Tables 5-14, 5-15 and 5-16.

In accordance with the Site Health and Safety Plan (Golder 1992a), a three person team was used during air monitoring along the trench bottom. Two people conducted the actual survey along the trench bottom while the third person remained outside of the subsidence trench and maintained visual and/or audible contact with personnel inside the trench.

The Foxboro Century System Model OVA-128 Portable Organic Vapor Analyzer (OVA) and the Thermo Environmental Model 580A Organic Vapor Monitor (OVM) instruments were used in conducting the air monitoring surveys. The OVA and OVM are highly sensitive electronic instruments designed to measure trace quantities of organic materials in air by means of a flame ionization detector (FID) and photoionization detector (PID), respectively.

Calibration, operation and use of the OVA and OVM instruments were conducted in accordance with the controls specified in GAI procedure P-12.0-1, “Calibration and Maintenance of Measuring and Test Equipment” as referenced in the QAPP. In addition, the OVA was used in accordance with procedure TP-2.3-2, “Calibration, Operation and Maintenance of Organic Vapor Analyzers”, as referenced in the QAPP. Instruments were calibrated at the start and at the conclusion of each air monitoring survey. In addition, the instruments were periodically checked and recalibrated if necessary during the course of the surveys.

Additional air monitoring was conducted in association with monitoring well drilling. A Microtip PID instrument was used for air monitoring during drilling operations. Calibration and use of the Microtip followed procedures as detailed above. Air monitoring procedures during drilling operations consisted of periodic checks for the presence of organic vapors in work area breathing zones and in air being discharged from the borehole. These data were recorded on health and safety data sheets and are discussed in Chapter 5.

2.2 Task 4 - Facility Environmental Assessment

A Level I Environmental Assessment (EA) was completed for the Landsburg Mine site and is included as Appendix A of this report. The EA was completed utilizing many of the same resources available for the remedial investigation. The purpose of the Level I EA was to identify historical land uses, ownership, or activities that may have resulted in the generation, storage or disposal of hazardous materials at the site. Although considerable information is available concerning mining and subsequent waste disposal activities within the subsidence trench, the EA focused on locations outside of the trench and on activities prior to and during mining operations potentially unrelated to waste disposal, that may have lead to environmental degradation. Such activities could have included fuel oil storage and general equipment maintenance areas where underground or above ground storage tanks may have been housed and degreasing solvents may have been used.

The Level I EA also examined the areas surrounding the Landsburg Mine site to determine if previous land use or private or commercial activity may have impacted the subject property. The EA did not include any additional (beyond that which was conducted in conjunction with the RI) soil, surface or ground water sampling.

The EA included the following activities:

- A review of the title history for the site.
- Interviews with personnel who may have been knowledgeable about site activities.
- A review of available ground water quality data and background information regarding development of the site.
- A comprehensive review of federal and state environmental databases which monitor the use of regulated and hazardous materials.
- An aerial photograph review.
- A visual reconnaissance of site conditions as described by personnel conducting the remedial investigation.

2.2.1 Title History Report

Golder contracted with Stewart Title Insurance of Seattle, Washington to complete a title history search for the Landsburg Mine site properties. The purpose of the title review is to identify previous land owners and to determine if the site may have ever been used for generation, storage, or disposal of hazardous materials. The title history describes site ownership from the 1940's to the present.

2.2.2 Interviews

Golder interviewed state and local representatives in order to gather additional site information that may not have been included in other sources. This process also included discussions with the Landsburg Mine property owners and mining company personnel, waste haulers and neighbors who may have been knowledgeable of site waste disposal activities. The interviewees were questioned about underground storage tanks, septic systems, material spills, or any incident or activity related to environmental issues.

2.2.3 Review of Available Ground Water Quality Data

Evaluation of historical groundwater quality data provides a base to assess if any ground water quality degradation has occurred as a result of activities at the site or surrounding properties. Golder reviewed a report from the Washington State Department of Health titled *An Evaluation of Drinking Water Quality In The Vicinity of the Landsburg Mine, Ravensdale, Washington* (WDOH 1992). The report was completed in February 1992 and discusses water quality sampling and analysis performed for ten residential drinking water wells surrounding the mine and from the City of Kent's Clark Springs Well. In addition to the 10 private wells, water samples from the south portal (portal #2) of the mine were also obtained and analyzed.

2.2.4 Review of Government Records

Golder contracted with Environmental Data Resources, Inc. (EDR) of Southport, Connecticut to perform a search of all available federal and state environmental databases to identify listings within a one mile radius of the Mine site. The databases included federal and state hazardous waste cleanup lists, lists of registered and leaking underground storage tanks, small quantity hazardous waste generators, and hazardous waste usage notifiers. The search was completed in conformance with current ASTM Standards (E-1527).

2.2.5 Aerial Photograph Review

Golder contacted both private and government agencies in order to gain information about aerial photographic coverage of the site. Walker & Associates of Seattle, Washington, David C. Smith & Associates of Portland, Oregon and Western Aerial Contractors, Inc. of Eugene, Oregon were contacted for information. In addition, the Cartographic Branch of the National Archives, the U.S. Department of Agriculture Aerial Photographic Field Office, the Washington State Department of Natural Resources and the King County Assessor were also contacted.

Based on these sources a review of available aerial photographs dating from the 1930's to the present was conducted in order to obtain information concerning development of the site and surrounding areas. The site and surrounding areas were examined for evidence that hazardous materials were generated, stored or disposed. One aerial photograph was available for each decade with the exception of the 1940's and 1950s. The lack of coverage during those years is attributed to the relative remoteness of the location at that point in time.

2.2.6 Site Reconnaissance

Site reconnaissance was completed as part of the continuing remedial investigation activities. Subsequent to the field work, an Environmental Assessment checklist was prepared based on observations and notes from field staff. Features evaluated through the site reconnaissance include a description of physical features such as topography, surface water drainage and the presence of cultural features such as buildings and roadways. Observations of potential underground storage tanks, abandoned drums, stained soils, stressed vegetation or other possible signs of environmental distress were also recorded if noted.

2.3 Task 5 - Private Well Survey

The private well survey was conducted to document the location, ownership, usage and construction characteristics of private wells within the RI/FS Study Area (Figure 1-2). This was necessary in order to assess possible risks posed by potential migration of chemicals in groundwater, and also to provide supplementary data in support of hydrogeologic characterization. Based on the results of the survey and in consultation with the Washington State Departments of Ecology and Health, selected private wells were included in the quarterly groundwater sampling program.

2.3.1 Well Inventory, Inspection and Verification

The well inventory, inspection and verification was conducted, to the extent possible, for all private wells within the defined Study Area. In general, the Study Area boundaries were selected (by Ecology) to include the area within an approximately one-half mile radius of the Rogers Trench. The survey was conducted as follows:

- All available logs of wells within the Study Area were obtained from Ecology's well data files. Additional information on the wells within the Study Area was obtained from the Department of Health.

- Public notice was issued for well owners in the Study Area to contact Ecology. This consisted of a mailed newsletter to homes on the Landsburg Mine site mailing list and an article in the November 24th, 1993 edition of the *Voice of the Valley* newspaper.

- The identified wells were then field inspected to verify their existence, current ownership, use, construction, condition, water levels, and other relevant details.

- In addition, suspected locations for unreported wells were visited within the Study Area.

A total of 56 private wells, providing water for approximately 91 homes and approximately 236 people, were identified within or near the Study Area. Some of these wells were located slightly outside the Study Area boundaries, but were included in the survey in consideration of requests made by the well owners to Ecology. Table 2-1 summarizes the results of the well inventory, inspection and verification. The approximate well locations are illustrated on Figure 2-2. Copies of available well logs are included in Appendix B. Information gathered during the private well inventory and inspection was used to assist in Study Area hydrogeologic characterization (Section 3.5), and in the selection of specific private wells to be included in quarterly groundwater sampling (Task 10). The results of the well survey are discussed in greater detail in Section 3.7.2.2.

2.3.2 Selection of Private Wells Included in Groundwater Sampling Program

Thirteen private wells and the City of Kent-Clark Springs facility were selected by Golder Associates, with approval from Ecology and the Washington State Department of Health (WDOH), for inclusion in the quarterly groundwater sampling program. The selection criteria consisted of the following considerations:

- Geographic/hydrogeologic location. Priority was given to those wells located potentially downgradient of the site. In addition, priority was given to those wells considered to be representative of the deeper groundwater system or to be of value in characterizing the Study Area hydrogeology. In addition, a representative number of upgradient wells were also selected to obtain indications of background water quality.

- Availability of access. Preference was given to wells having sampling ports that facilitated the collection of representative groundwater samples (i.e., wells with ports on or near the well head). Wells with poor surface seals, abandoned wells or wells without operating pump systems were not considered for inclusion in the sampling program.

- Water use. Preference was given to those wells that are utilized as drinking water sources. Private wells that supply drinking water to multiple homes were given priority.

- Owner requested well to be included in RI/FS sampling program. Preference was given to those wells that met the above criteria and whose owner(s)/tenant(s) requested their wells be included in the groundwater monitoring program. Requests were submitted in response to the above mentioned Public Notice and from public comments submitted during a Public Hearing held on June 30, 1993 at the Central Service Building of the Tahoma School District.

Following selection of the 13 private wells and the City of Kent-Clark Springs facility, access agreements, permitting access to the well owner's properties, were obtained from the 14 selected well owners/tenants. Mr. Steve Hulsman, from WDOH, assisted GAI personnel during initial contact with well owners and during initial field inspection of private well systems. Groundwater sampling and analysis of the private wells was performed in accordance with the monitoring well quarterly sampling program detailed in Section 2.8.1. Groundwater sampling was conducted similarly to procedures used by Mr. Hulsman during the private well sampling conducted previously by WDOH (as described in Section 2.2.3 of this report).

2.4 Task 6 - Surface Water Sampling and Flow Monitoring from Portals #2 and #3

Discharge of groundwater to the surface occurs at the northern end (portal #2) and at the southern end (portal #3) of the Landsburg Mine (Figure 2-3). These surface flows are believed to represent a discharge of groundwater from the mine through collapsed portals. In order to assess the significance of groundwater discharge from the mine as a contaminant migration pathway, a program of periodic monitoring was established in which water quantity and water quality data were collected.

2.4.1 Flow Monitoring

Groundwater discharge to the surface at portal #2 is confined within the boundaries of a small pool in a depression at the northern end of the subsidence trench. No actual flow from the portal was observed by Golder during the RI. Fluctuations in water levels at portal #2 were monitored through periodic water level measurements utilizing installed staff gauges. Two staff gauges were required to measure periods of high and low water levels. The staff gauges were installed within the pooled water and were tied into the site's geodetic system.

Groundwater from portal #3 is discharged to the surface from a seepage area at the southern end of the mine site. Down slope of the seepage the natural topography directs the discharge into a narrow channel. Within this channel system a small collection dam was constructed (Figure 2-4). The collection dam captures the seepage water and directs it through an eight inch PVC pipe. Water discharge flow rates from the PVC pipe were periodically monitored by capturing a known volume of water in a measured amount of time and then calculating the flow rate in gallons per minute. During periods of high precipitation, surface runoff water was also naturally collected in the dam and measured with the flow rate.

Water level measurements collected from portal #2, as well as flow rates collected from the portal #3 seepage, have been compiled and are graphically illustrated in Appendix B.

2.4.2 Surface Water Sampling

The collection of surface water quality data has been conducted through quarterly sampling and analysis of water emanating from portal #2 in the northern portion of the mine and from portal #3 in the southern portion of the mine. Four sampling events have been completed. The first sampling event was conducted in April 1994. Subsequent sampling events occurred in August 1994, December 1994 and March 1995. Surface water analytical data have been compiled and are provided in Table 5-5 of this report. Complete analytical summary tables are included in Appendix C. Some surface water sampling was previously performed in 1990 by Geraghty and Miller, Inc. (1990). Results of the 1990 sampling event are discussed in Section 3.2.2.

Sample collection and handling followed strict QA protocols and procedures as outlined in the QAPP. Just prior to or immediately following collection of surface water samples, the pH, temperature, electrical conductivity, and turbidity were measured. All instruments used for field analysis were calibrated in accordance with procedure P-12.0-1, "Calibration and Maintenance of Measuring and Test Equipment ."

Samples were collected in properly cleaned bottles of appropriate volume and type and were preserved as directed by the analytical facility. After filling, the bottles were sealed, labeled and placed in a cooler maintained at 4^{o} C. Samples were then transported to the analytical facility under formal chain of custody documentation in sufficient time to conduct the requested analyses within the specified holding times. All analyses were completed on un-filtered samples. Samples for metals analysis were field acidified.

Documentation of sampling included bottle labels, completion of Sample Integrity Data Sheets, Field Report Forms and Chain of Custody Records. Chain of custody was maintained in accordance with the procedure TP-1.2-23, "Sample Handling and Chain of Custody."

Portal #2 surface water samples were collected directly from an undisturbed area of the accumulated water. Unpreserved sample containers were filled by completely submerging the container under the water until full. The sample containers containing preservatives were filled by transferring water from one of the clean sample containers into the preserved sample container(s).

Portal #3 surface water samples were collected directly from a one-inch perforated PVC pipe which was driven laterally into the natural slope of the seepage area. The seepage area has an approximate 2 to 3 percent slope which allows discharge from the inserted perforated PVC pipe. A small pit was dug under the discharge end of the PVC to allow space for sample containers to be placed during filling. The PVC pipe was initially driven into the seepage and left undisturbed approximately four hours prior to collection of the first quarter samples. The pipe was left in-place and was utilized for each subsequent sampling round.

Surface water samples collected from portals #2 and #3 were analyzed for Target Analyte List (TAL) metals, cyanide, wet chemistry/anions, volatile organics (EPA Method 524.2), semivolatile organics (EPA Method 8270), pesticides and PCBs (EPA Method 8080 first, second and fourth quarters, EPA Method 508 third quarter). General water quality parameters and drinking water standards were also analyzed. In addition, analysis by EPA Method 525 (pesticides/PAHs) was conducted during the first and third quarter sampling rounds. The 500 series analysis were performed by Inland Environmental Laboratory in Spokane, Washington; all other analyses were conducted by Analytical Resources Incorporated in Seattle, Washington. Table 2-2 summarizes the surface water sampling activities, including sample identifications, dates of sampling, and analyses conducted.

2.5 Task 7 - Surface Soil Sampling

The surface soil sampling program was designed to determine and assess the extent of potential impacts on surface soils and possible contaminant exposure due to past waste disposal activities along the rim of the trench. This task was aimed at characterizing soils which are located outside of the mine subsidence trench only. Some materials within the trench have been analyzed previously in the Site Hazard Assessment by Ecology and Environment (1991) and the report on the Landsburg Mine Drum Removal Project by Landsburg PLP Steering Committee (1991). These results are discussed in Section 3.2.2.

Surface soil sampling was conducted along the trench rim perimeter and in the drainage areas of portals #2 and #3. Table 2-3 provides a summary of surface soil sampling activities. Soil sampling analytical results are discussed in Section 5.2. Summary tables of all soil sampling analytical results are provided in Appendix C.

2.5.1 Trench Rim Perimeter Soils

Surface soil sampling was conducted for the trench rim perimeter soils to assess potential contamination associated with historic waste disposal and handling activities which occurred along the trench rim area. Additional potential sources of surface soil contamination may also be attributed to material handling and equipment decontamination activities associated with the drum removal efforts conducted by the Landsburg PLPSC in 1991. Available records have indicated that most waste handling, placement, and removal activities and equipment decontamination took place within two access areas on either side of the mine trench. These areas, designated Access Area 1 and Access Area 2, are shown in Figure 2-5. These are the areas where sampling was focused. An additional control area was selected for soil sampling in a portion of the site away from previous waste disposal/waste handling activities and is expected to be representative of background levels.

Golder personnel conducted the trench rim soil sampling task on November 11-12, 1993. A total of 13 composite soil samples were collected for analysis. Of the thirteen samples, four were collected from Area 1, four from Area 2, four were collected from the selected background area, and one duplicate sample was collected. The locations of the samples are shown in Figure 2-5. Each of the samples was comprised of a composite of four discrete sub-samples taken from within zones chosen on the basis of the site selection criteria described below. Four zones were established in each area. In Areas 1 and 2, three of the four zones were selected as suspect areas defined on the basis of the following criteria:

- presence of vegetative stress,
- presence of soil discoloration,
- history of past waste storage and disposal,
- proximity to known waste handling or equipment decontamination areas.

The fourth zone in Areas 1 and 2, consisted of the entirety of the area, exclusive of the three previously selected zones. The four background soil sampling sites were defined by dividing the background area into four equal quadrants. Composite samples were then collected from within each quadrant. The duplicate sample was collected at one of the previously sampled sites, selected at random by field personnel.

From within each of the selected sampling zones, four subsamples were collected from the upper three to six inches of soil from discrete random locations. The subsamples were composited into a single sample within the sample containers. After compositing and filling, the sample bottles were immediately sealed, labeled, and placed in a cooler maintained at 4^{o} C. All samples were transported under formal chain of custody procedures to Analytical Resources, Inc. in Seattle, Washington for laboratory analysis. Soil samples were submitted for Target Analyte List (TAL) metals, cyanide, volatile organics (Method 8240), pesticides/PCBs (Method 8080), semi-volatile organics (Method 8270), and anions (Cl, F, SO_4, NO_2, and NO_3).

All surface soil sampling activities conducted under this task were performed in accordance with Golder Technical Procedure TP-1.2-18 “Technical Procedure for Sampling Surface Soil for Chemical Analysis” as referenced in the QAPP. Samples were collected in properly cleaned bottles of appropriate volume and type as specified in the QAPP. All equipment utilized was properly decontaminated prior to collecting soil at each sampling location. Decontamination of the sampling equipment consisted of a non-phosphate detergent rinse, followed by a reagent-grade methanol rinse, then an approved tap water rinse, and a final organic free distilled/ deionized water rinse.

2.5.2 Portal Soils

The portal #2 and portal #3 surface soil sampling program was designed to determine and assess the extent of potential impacts on nearby surface soils due to potential contaminant migration through the mine workings and groundwater discharge to the ground surface at the portals. Because the portals represent an avenue of potential contaminated groundwater discharge from the mine, surficial materials adjacent to and downgradient from the drainage of each portal were sampled.

A total of four samples were collected from along the drainage at each portal area. Figures 2-5 and Figure 2-6 show the location of samples collected at portal #2 and portal #3, respectively. Sample locations were at approximate 50 foot intervals. Each sample consisted of a discrete sample collected from within the upper three to six inches of the soil column. One soil sample was collected at the opening of the Frasier Seam drainage (sample FNS-1), a possible background location (Figure 2-5). Surface soil sampling from portals was conducted by Golder personnel on February 18, 1994. Soil sampling was conducted using procedures outlined in Golder Technical Procedures TP-1.2-18, "Technical Procedures for Sampling Surface Soil for Chemical Analysis."

All soil samples collected under this task were shipped under formal chain of custody to Analytical Resources, Inc. in Seattle, Washington for analysis. Soil samples were submitted for Target Analyte List (TAL) metals, cyanide, volatile organics (Method 8240), pesticides/PCBs (Method 8080), semi-volatile organics (Method 8270), and anions (Cl, F, SO_4, NO_2, and NO_3). Equipment decontamination procedures were identical to those used for the trench rim soil sampling

2.6 Task 8 - Geophysical Investigation

2.6.1 Source Characterization in Rogers Trench

Source characterization of the Rogers Trench was accomplished using magnetometry for the ground geophysical survey. The magnetometer measures the earth's natural magnetic field and detects variations (i.e. anomalies) in this field caused by ferrous objects. In gradiometer mode the magnetometer utilizes two sensors to measure the total magnetic field and the vertical gradient of the field. The magnetometer survey consists of recording measurements of the magnetic field at fixed intervals along a survey transect. The data are plotted in profile to identify distinct anomalies in the magnetic field. Magnetometer surveys are useful in environmental investigations since significant magnetic anomalies are often produced by buried ferrous objects, such as pipelines, steel drums, and storage tanks. The magnitude of the anomaly produced by the object is dependent on its size, orientation, depth of burial, and magnetic properties. In addition to changes in the earth's magnetic field caused by ferrous objects, there are changes resulting from solar storms, and diurnal drift. A base station was established and re-occupied periodically during the survey to monitor these variations. The base reading was then used to correct the data for significant diurnal variations.

The geophysical survey in the trench was restricted to magnetometry since a primary aim was to identify buried metallic debris. Use of other techniques, such as EM, would not be expected to provide significant additional benefit. Use of GPR was prohibitive due to access difficulties associated with operating the GPR equipment in the trench.

The magnetometer survey was conducted with an EG&G 856 proton precession magnetometer that is capable of total field and vertical gradient measurements. This is a portable instrument consisting of two sensors mounted on a staff and a digital display unit carried in a harness by the operator. The data are recorded digitally in the instrument memory and later downloaded to a computer.

All geophysical characterization work was conducted by ground surveys. The Work Plan (Golder 1992a) originally anticipated that portions of the geophysical survey were to be conducted by aerial reconnaissance. Geophysical instruments were to be deployed via a cable or cargo net suspended below a helicopter. Upon further inspection of site conditions and in consultation with the project geophysicist and helicopter operators, it was determined that suspended geophysical instruments could potentially become entangled in the heavy brush which is prevalent throughout the mine site. In consideration of this safety issue, and coupled with the fact that equivalent or better data could be obtained by ground surveys, it was decided that the aerial surveying should not be attempted.

The ground magnetometer survey was conducted on September 30, October 1, 15 and 21, 1993. The survey was conducted along the central axis of the Rogers Seam following 100 foot station markers established along the mine workings. The station markers began with 0+00 at the south end of the seam and ended with 48+20 at the north end of the seam (near Summit-Landsburg Road). Figure 2-7 shows the locations where the geophysical surveys were conducted.

The area is heavily vegetated and it was necessary to clear a trail for much of the survey line. In areas where it was not possible to access the bottom of the surface depression the stationing was extended perpendicular to the seam along a trail on the east side of the mine. The 100 foot stationing was continued along this trail until access could be reestablished. The offset stations were then extended back to the eastern edge of the surface depression. The stations at the edge of the depressions were easily visible from within the depressions during data collection. Irregularities in the straightness of the survey line, laying the survey tape over surface obstructions, and extending stationing perpendicular to the axis of the seam all contributed to a degree of error in the 100-foot stationing. Therefore, the stationing is considered rough control for conducting the survey and relocating areas of interest.
Total field and vertical gradient data were collected at 10-foot intervals along nearly the entire length of the seam. The 10-foot intervals were based on pacing between the 100-foot control points. Three small data gaps exist (19+60 to 19+90, 25+90 to 26+10, and 31+90 to 32+50) due to an inability to access the base of the trench at those areas. Results of the geophysical survey

are discussed in Section 3.2.3 of this report and are graphically depicted in Figure 3-6. Raw geophysical data are included in Appendix K.

2.6.2 Geophysical Surveys at Monitoring Well Locations

Additional geophysical surveys were conducted to assist in the determination of monitoring well drilling locations. The objective of the surveys was to locate the coal seam at four of the proposed drilling sites (LMW-2&4, LMW-3&5, LMW-6, and LMW-7). At the fifth site (LMW-1), the objective was to locate a tunnel which connects two sections of the Rogers Seam offset by a fault. To achieve these objectives, the electromagnetic (EM-31 and EM-34) and ground penetrating radar (GPR) methods were employed. Figures 2-7 to 2-12 indicate the areas where EM and GPR surveys were conducted. Additional information regarding determination of well locations is presented in Section 2.7.1. The raw geophysical data are included in Appendix K.

An electromagnetic (EM) survey measures terrain conductivity. Variations in terrain conductivity are produced by buried materials, various soil and rock types, and hydrogeologic conditions. These would include the presence of coal-bearing strata and also large voids such as the rock tunnel. EM instruments introduce an electromagnetic field into the ground via a transmitter coil. This field generates eddy currents in the subsurface which produce a secondary magnetic field that is measured by the receiver coil along with the primary field. The ratio of electromagnetic field detected by the receiver coil to the electromagnetic field produced by the transmitter coil is directly proportional to terrain conductivity. The instrument is designed to convert this ratio to a reading of millisiemens per meter (mS/m). These readings are known as the quadrature components and are presented in this report as terrain conductivity values.

The EM surveys were conducted using the Geonics EM-31 and EM-34 instruments. The EM-31 is a portable one-person instrument with a transmitter and receiver coil at opposite ends of a 12-foot boom with a display meter at the center. The EM-34 is a two-person instrument with a transmitter and receiver coil attached by a cable with a display meter carried by one operator. The EM-34 can take measurements at 10, 20, and 40 meter coil separations. A larger coil separation produces a conductivity measurement for material at greater depth.

Measurements can be made with the coils oriented both horizontally and vertically. The vertical orientation provides information from greater depth than the horizontal mode. The EM-31 has a maximum penetration depth of about 18 feet. The EM-34 has a maximum penetration depth of 50, 100, and 200 feet for the 10, 20, and 40 meter coil separation, respectively.

Ground penetrating radar (GPR) is a high frequency electromagnetic technique which transmits radar pulses into the subsurface and records the subsequent radar pulse reflections. A radar antenna is pulled along the ground surface, and radar pulses are transmitted into the ground for every few inches of forward motion. The transmitted pulses are reflected from subsurface discontinuities that have contrasting electrical properties. Reflections can be produced by a number of subsurface conditions: layering in the soils; changes in moisture content; the water table; discrete objects such as pipes, drums, storage tanks, and miscellaneous debris. A graphic record is produced in the field which depicts a cross-sectional view of the subsurface along the survey transect. A location mark, indicated by a vertical line on the GPR records, is recorded by the geophysical technician pulling the antenna as the antenna crosses locations marked on the ground.

The GPR survey was conducted with a GSSI SIR System 4. This system consists of a 120 or 300 Mhz antenna, a control unit, and a 200-ft cable connecting the antenna to the control unit. The data were displayed on an EPC 8700 thermal graphic recorder. The system was powered by two 12-volt automotive batteries.

Site LMW-1

The objective of the geophysical survey at LMW-1 was to locate a tunnel connecting two sections of the Rogers Seam that are offset by a right-lateral fault. The fault and suspected tunnel are located where the access road crosses the Rogers Seam. The well was to be located to intercept the tunnel.

The electromagnetic survey was performed along two survey lines oriented perpendicular to the strike of the tunnel and separated by 20 feet as shown on the site sketch map (Figure 2-8). Each survey line was run at a ten foot station spacing with the EM-31 and a 20 foot station spacing with the EM-34. Coil separations of 10, 20, and 40 meters with the EM-34 were used to sound different depths of investigation.

The EM-31 profiles show a sharp increase in conductivity between 80 and 120 feet on line 1 and between 70 and 120 on line 2. This conductivity increase is interpreted to be possibly the location of the tunnel. The EM-34 profiles also show an increase in conductivity at approximately 80 feet, however, due to the large coil separation, the other side of the anomaly is not well-resolved.

Historical records indicate that the tunnel is at a depth of 180 feet. At that depth any influence on the conductivity measurements would be expected to be apparent in the larger coil separations and the vertical mode of the EM-34 profiles. The EM-34 vertical mode profiles for line 1 show a small decrease in conductivity between 60 and 80 feet at the 20m and 40m coil separation. The EM-34 vertical mode profiles for line 2 show a conductivity minimum at 80 feet for the 40m coil separation. The 20m separation shows a minimum at 60 feet and a sharp decrease at 120 feet. The low reading at 120 feet is not consistent with any other profile and is considered a noisy reading. These decreases in conductivity may possibly show the influence of the tunnel directly or a change in hydrogeologic conditions caused by the tunnel. Based on these conductivity lows, it was estimated that the tunnel is between 60 and 80 feet on survey line 1.

A line was also drawn connecting the terminus of the surface depressions on either side of the survey area. This line represents a rough geometrical estimate of where the tunnel is expected to be located. This line crosses survey line 1 at 77 feet. This is in close agreement with the estimate of 60 to 80 feet based on the geophysics.

Site LMW-2 & LMW-4

An electromagnetic survey was performed at the original LMW-2 and LMW-4 site (adjacent to the Cedar River pipeline road) to locate the northern portion of the Rogers coal seam for drill hole placement. A GPR and radio-detection survey were then performed in the vicinity of the suspected seam location to locate the City of Seattle water pipeline and any other utilities that may affect or be impacted by drilling operations.

The electromagnetic survey was performed along four survey lines oriented parallel to Pipeline Road and perpendicular to the strike of the coal seam as shown in Figure 2-9. Lines 1-4 were surveyed with the EM-31 at a station spacing of 10 feet. The EM-31 conductivity profiles show a conductivity low at approximately 170, 150, and 130 feet on lines 1, 2, and 3 respectively. These conductivity lows are interpreted to be the location of the coal seam. The alignment of these three conductivity lows gives a strike that is consistent with the overall strike of the coal seam. The EM-31 response along line 4 was flat with a lower conductivity value. Line 4 is located along the north side of Pipeline Road close to the power lines and the Cedar River. The lower conductivity and flat response is thought to be a combination of interference from the power lines and possible sandy sediments associated with the Cedar River.

The use of the EM-34 at this site was limited by power line interference, thick vegetation, and topography. The EM-34 is susceptible to powerline noise, especially at large coil separation. Therefore the EM-34 survey was run at the 10m and 20m coil separation along line 1 (the line furthest away from the power lines). The EM-34 conductivity profiles for line 1 (horizontal mode) show a similar shape as the EM-31 profiles but the conductivity variations were much more subtle. The cause of the negative values at the 10m coil separation is unknown but may be the result of the powerlines. The vertical mode profiles were very noisy and cannot be reliably interpreted.

The objective of the GPR survey at this site was to locate the water pipeline and any other utilities that exist in the area. A total of 15 transects were run from approximately 10 feet south to 100 feet north of Pipeline Road (Figure 2-9). The coverage extended from approximately 100 feet east to 200 feet west of the coal seam location determined from the electromagnetics survey. In addition to the GPR survey the area was covered with a model RD-400 radio-detection instrument. This instrument is a Very Low Frequency (VLF) receiver and is capable of detecting conductive utilities like cables and metallic pipe. Several pipe-like GPR targets and one radio detection target were found within the area. A pipe-like GPR target was found just south of Pipeline Road on lines 70E to 120W at a depth of 8 to 12 feet. A second pipe-like GPR target was identified on all the transects approximately 7 feet north of the south edge of Pipeline Road at a depth of 3 feet. A third pipe-like GPR target was identified just north of Pipeline Road on lines 10W to 200W. A radio-detection target was identified approximately 3 feet north of the 3 foot deep GPR target within the road bed. The radio-detection target is thought to be the telephone cable that is said to be buried along the road. Later backhoe excavation to the top of the water supply pipeline identified the 3 foot depth GPR target within the road bed as the City of Seattle water line. The excavation was not dug to great enough depth to identify the other GPR targets. Continuing concerns about the condition of the old concrete City of Seattle water supply pipeline as well as difficult drilling access, resulted in relocating LMW-2 and LMW-4 to their present position.

Site LMW-3 and LMW-5

LMW-3 and LMW-5 are located at the southern end of the Rogers Seam. The objective of the geophysical investigation at this site was to locate (for drill hole placement) the coal seam and a mine portal that had been collapsed and bulldozed over. An issue at this location involved possible interferences from the nearby powerlines. This is the only location at the site where powerline interferences was a concern. The possible interference is limited to the EM data as GPR is not affected by power lines. The extent of the EM interferences is discussed below.

The GPR survey consisted of six lines run perpendicular to the strike of the coal seam and one line run semi-parallel to the coal seam as shown in Figure 2-10. Two GPR targets were identified at 118 feet on line 1 and 110 feet on line 2. These targets identify areas of increased signal strength on the radar record about 20 feet wide. These targets are interpreted as possible coal seam locations. A pipe-like GPR target was followed from lines 1 and 2 south to the portal #3 seepage area. This may be a drainage pipe from a portal feature. The north-south GPR line shows a decrease in signal amplitude in the wet area compared to the drier areas to the north and south. This indicates a change in soil or moisture conditions in this area.

The EM survey consisted of surveying the GPR anomalies along GPR lines 1, 2, and 3 with the EM-31 and EM lines 1, 2 and 3 with the EM-34 (Figure 2-10). The EM-31 showed background conductivity values of 35-40 mS/m that decreased to 0-15 mS/m over the GPR anomalies GPR-1 and GPR-2. This response is consistent with a change in soil type produced by a coal seam.

The EM-34 was affected by interference from the powerlines to the south. Oscillations of 10 mS/m were observed on most lines while in a stationary position. The conductivity profile for the lines and coil separations where data were recorded show an increase in conductivity for the vertical mode from 100 to 160 feet on line 1. This is the area around GPR anomaly GPR-1 and also suggests a possible change in soil type. The reason for increased conductivity values with the EM-34 and decreased conductivity values with the EM-31 is unknown, but powerline interference with the EM-34 is one possible explanation. In the horizontal mode reasonable data could only be recorded at the 10m coil separation. These data show little response along profile. The negative values for this mode suggests the readings are affected by powerline noise.

Reasonable data could only be collected at the 10-meter coil separation and vertical mode for line 2. The conductivity values show a general increase between 100 and 160 feet with a sharp decrease at 140 feet. Interference from the power lines was especially bad on this line and the reliability of these readings for interpretation are questionable.

Line 3 was located along the trail crossing the strike of the coal seam just south of the first surface depression on the Rogers Seam. The origin of the magnetometer survey is located at -5 feet on line 3 and this should be the approximate location of the coal seam crossing. The horizontal mode shows a decrease in conductivity upslope from 100 to 20 feet and a level response from 20 to -100 feet. The vertical mode shows a decrease in conductivity from 10 to -80 with a minimum at -40 feet and -20 feet for the 10m and 20m coil separation. These conductivity minimums in the vertical mode probably indicate the coal seam.

Site LMW-6

The objective of the geophysical survey at LMW-6 was to locate the Frasier coal seam for drill hole placement. The general location of the seam was taken from maps of the mine showing the location of the Frasier Seam in relation to the access road that crosses it.

The EM survey consisted of EM-31 and EM-34 surveying along 3 lines oriented perpendicular to the strike of the coal seam as shown in Figure 2-11.

EM-31 data were formally recorded for line 1. On lines 2 and 3 only the location of anomalies were flagged. The conductivity profile for line 1 shows a maximum conductivity at 80 feet. This conductivity maximum is interpreted as the coal seam location with the increase in conductivity resulting from an increase in near surface moisture. Two conductivity minimums were flagged on lines 2 and 3 at 104 feet and 118 feet respectively and are interpreted as the location of the coal seam. The alignment of these three anomalies gives a strike direction consistent with that shown on mine maps.

EM-34 data were recorded at all three coil separations for line 1. The horizontal mode data show a consistent decrease in conductivity along line 1 and no anomalous reading at the location of the EM-31 anomaly. The vertical mode data, however, show a conductivity minimum at 80 ft and 60 ft for the 10m and 20m coil separation. The opposite sign of this anomaly compared to the EM-31 data can be explained by the deeper depth of investigation, the EM-34 readings are more influenced by the shallow geology and less by the near surface moisture conditions. On line 2 the EM-34 data show a subtle minimum at 80-100 feet. This is in close agreement with the EM-31 anomaly at 104 feet. On line 3 the horizontal mode EM-34 data show a subtle minimum at 120 feet, 2 feet from the EM-31 anomaly at 118 feet. The vertical mode EM-34 data was scattered and show no interpretable trends.

Site LMW-7

The objective of the geophysical survey at LMW-7 site was to locate the Landsburg coal seam. The general location of the geophysical survey was based on a seam location from a geodetic survey crew that relocated the seam from old mine maps.

The electromagnetic survey consisted of EM-31 surveying along 3 lines oriented perpendicular to the strike of the coal seam as shown in Figure 2-12. EM-34 surveying was performed on line 1 only.

The EM-31 conductivity profiles show a relatively flat response along line 1. The conductivity minimum at 120 feet is within 10 feet of the seam location based on old mine maps at 110 feet. The conductivity minimum is less than 1 mS/m different from the surrounding data values. Although the conductivity minimum and surveyed seam location are in good agreement, the conductivity minimum is more subtle than would be expected from a coal seam. Line 2 shows a conductivity maximum at 110 feet. The conductivity variation along line 2 corresponds to local topography with the conductivity maximum at the base of a local depression. These conductivity variations probably indicate variations in moisture content from small scale topography. Line 3 shows a conductivity maximum at 120 feet. This corresponds to a wet area on the surface and is probably related to near-surface moisture content.

The EM-34 conductivity profiles show a relatively flat response along line 1. No anomalies are seen on the horizontal or vertical mode data that could be interpreted as a coal seam.

2.7 Task 9 - Monitoring Well Drilling and Installation

The purpose of installing groundwater monitoring wells was to obtain hydrogeologic, chemical, and hydraulic data to assess the hydrogeologic conditions in the immediate vicinity of the mine and to determine the extent and potential migration of any chemical compounds. A total of seven monitoring wells were completed during the RI. The seven monitoring wells were designated LMW-1 through LMW-7 (LMW - Landsburg Monitoring Well). In addition to the seven monitoring wells, a temporary monitoring well, designated LMW-1A, was completed during drilling operations in the LMW-1 area.

2.7.1 Determination of Well Locations

Monitoring wells LMW-2/LMW-4 and LMW-3/LMW-5 were completed as clustered monitoring wells that monitor shallow and deeper zones of the Rogers coal seam. The LMW-2 and LMW-4 wells were set in the northern portion of the Rogers Seam, and LMW-3 and LMW-5 wells were set in the southern portions of the Rogers Seam. Monitoring of hydrologic conditions in the Frasier seam and the Landsburg seam, located to the east and west respectively of the Rogers Seam, was accomplished through the installation of LMW-6 in the Frasier seam and LMW-7 in the Landsburg seam. LMW-1 was located to intercept the tunnel which was constructed during mining operations to connect sections of the Rogers coal seam offset by a fault. Monitoring well locations are shown in Figure 2-3.

A thorough understanding of coal seam locations and the fault zone tunnel location was required in order to properly determine monitoring well drilling sites. As such, the geophysical surveys, described in section 2.6.2, were performed at each of the proposed monitoring well locations. In addition, Cramer & Niclas, Inc. of Kent, Washington were contracted to conduct geodetic surveying of the coal seam locations and the location of the fault zone tunnel. The geodetic surveys were based on projecting the locations of the coal seams from historical mining maps to the surface in the area of the drill site.

Based on a combination of the geophysical and geodetic surveys, a surficial projection of the coal seams was established at each drill site. Utilizing the surface projections and recorded information on the dip of the coal seam and tunnel depth, drilling locations and estimated depths were then established for the seven monitoring wells.

Boreholes LMW-2 and LMW-4 were initially to be located just south of the Seattle Water Department's Lake Youngs Aqueduct (a 96-inch diameter water pipe with a 10-inch thick steel reinforced concrete wall). This location was originally chosen so that core samples of coal which had not been altered by mining activities could be obtained. The Seattle Water Department expressed concerns over the possibility of damage to the aqueduct from the weight of the drill rig and from ground vibrations produced during drilling. Upon further consultation with Seattle Water Department and with the approval of Ecology, LMW-2 and LMW-4 borehole locations were relocated to intercept the Rogers Seam at the northern most point downgradient of the mine workings but still on land owned by Landsburg PLP members (Figure 2-3).

2.7.2 Drilling and Well Installation

Burlington Environmental, Inc. of Groveport, Ohio was contracted by the PLP Group to perform all borehole drilling and well installation activities for the RI. All monitoring wells were drilled using the air rotary method with driven steel casing. Burlington utilized a Schramm T-660 rotary drilling rig and eight-inch diameter steel casing. The air compressor on the drill rig was equipped with an operable air filter to remove entrained hydrocarbons so the pressured air was of "D" breathable quality.

Prior to conducting any drilling operations, the rotary rig, drill rods, bits, and steel drive casing were decontaminated with a pressure washer and steam cleaner. The rig and tools were thoroughly decontaminated between each borehole drilling operation, and prior to demobilization from the site. Decontamination activities were conducted within the confines of a bermed plastic-lined decontamination area (Figure 2-13). Decontamination water was collected and stored in labeled 55-gallon Department of Transportation approved drums.

After decontamination, the air rotary rig was set up at each site using levels to ensure a stable, plumb borehole. Boreholes LMW-4 and LMW-7 were drilled at an angle (20 degrees off vertical) to aid in the intersection of the coal seam at depth. All other boreholes were drilled vertically. Drilling consisted of driving an eight-inch steel casing behind a 7 7/8-inch tricone bit until consolidated material was reached. The purpose of the steel casing was to maintain the open borehole in the unconsolidated soils and to channel all return circulation and cuttings through the casing to a cyclone, via a diverter and flexible hose. After setting the casing, drilling continued in the open borehole to depth by 7 7/8-inch tricone bit or 7 7/8-inch downhole hammer with button bit (dependent on drilling conditions). During drilling, grab samples of the encountered formation(s) were collected at five foot intervals for geologic logging and interpretation.

Cores of the Rogers coal seam were obtained from boreholes LMW-2, LMW-3, and LMW-5. The cores were obtained using a 2 1/8-inch inside diameter double-tube split core barrel with sample catcher. The first coring was conducted in the southern end of the Rogers coal seam during drilling of LMW-3 and LMW-5. Core sampling of the coal was conducted from 49.4 to 76 feet below ground surface (BGS) in LMW-3, and from 227 to 238 feet BGS in LMW-5. Core sampling in the northern portion of the Rogers coal seam was conducted from 25 to 35 feet BGS during the drilling of LMW-2. A new coring bit and core catcher were used for coring in LMW-2. No core runs were attempted on LMW-4 due to the unconsolidated nature of the coal seam at the depths it was encountered within this borehole (197 to 233 feet below ground surface). Core samples obtained were field logged, placed in plastic liners, and then stored in labeled wooden core boxes in accordance with Golder Technical Procedures TP 1.2-2 "Rock Core Logging." Cores were attempted using both air and potable water injection, but the presence of voids and the soft friable nature of the coal resulted in poor core recovery from all three wells. Photographs of the coal recovered during coring operations are displayed in Appendix D.

Boreholes LMW-2, LMW-3, LMW-4, LMW-5, LMW-6, and LMW-7 were located successfully to encounter the coal seams/mine workings as anticipated. Due to a communications error between GAI personnel and the geodetic surveyors, the first attempt (designated LMW-1A) at drilling into the fault zone tunnel was unsuccessful. The drill location was incorrectly interpreted from the mining maps. Additional surveying was conducted, and a second borehole was drilled in an attempt to intercept the fault zone tunnel. Interception of the tunnel on the second borehole (designated LMW-1) was inconclusive during drilling. No evidence of intercepting a void area was encountered during drilling of LMW-1 (i.e. loss of air pressure, drill rods freely falling, etc.), however, evidence of significant voids/fractures was observed during the well installation process (i.e. loss of grout and sand), and the well is believed to be in fairly good communication with the tunnel.

Upon drilling to the desired depth, each of the seven boreholes was completed as a monitoring well. A summary of the depths drilled and well completion details are included in Table 2-4. Individual borehole logs and monitoring well completion logs are provided in Appendix E. All monitoring well installations were supervised by a GAI hydrogeologist and constructed in accordance with Golder Technical Procedure TP-1.2-12 "Monitoring Well Drilling and Installation," as provided in the QAPP. These wells are also in conformance with State well construction regulations (WAC 173-160).

In general, the monitoring wells were completed using 4-inch diameter stainless steel well screen (15 feet in length) and casing with O-ring seals between the joints. Stainless steel, 4-inch nominal diameter, flush-coupled screen with a wire wrapped 0.020-inch slot was used. The well screens were centered in the borehole using stainless steel centralizers installed at the bottom and top of the screen and continued at a maximum 40 feet spacing. A 5 or 20 foot length of nominal 4-inch diameter stainless steel riser casing was installed above the screen. The remainder of the well to land surface was constructed using 4-inch, schedule 80 PVC, flush-coupled blank well casing.

With the exception of LMW-5 and LMW-7 a filter pack using 10/20 Colorado silica sand was installed to a depth approximately three feet above the topmost slot on the screen. The top of the filter pack was periodically measured during placement using a weighted engineering tape. A bentonite seal was then placed immediately on top of the filter sand pack. The bentonite seal was placed by hand pouring medium bentonite chips down the annulus and allowing sufficient time for the chips to hydrate. Following completion of the filter pack and bentonite seal, the remainder of the annular space was filled to the ground surface using a Volclay (bentonite grout) or a cement bentonite grout. All grout mixtures were injected into the annular space via a side discharge tremie pipe. The 8-inch steel outer casing was pulled in conjunction with the final grouting of the annulus.

The following well installation alterations were required to meet variabilities encountered at the mine site:

- After setting the sand pack and bentonite seal in LMW-1, attempts to fill the annulus with volclay grout failed due to the presence of a void and/or fractures located at approximately 100 to 140 feet below the ground surface. A column of 8-10 Colorado sand followed by a column of bentonite chips were utilized to fill this zone of the annulus. Volclay grout was then used to fill the annulus to the surface.

- Only a 10 foot screen was used in LMW-2 due to the shallow nature of the well.

- The 15 feet of stainless steel screen used in LMW-4 consisted of a bottom 10-foot prepacked screen welded to a 5-foot piece of regular screen. The prepacked screen was used in anticipation of the screen bottom becoming slightly embedded in the soft sloughed in material at the bottom of LMW-4.

- The screen section of LMW-5 was set in the southern portion of the Rogers Seam mine workings. The presence of the open mine workings precluded the setting of the filter pack. Thus, a 10-foot prepacked screen was used, and a stainless steel "catch" was welded to the riser pipe. The purpose of the catch was to serve as a platform on which the bentonite chips would bridge forming a seal in the annulus. A thick cement bentonite grout plug was placed above the bentonite chips, and the remained of the annulus was volcay grouted. The configuration of the catch device is shown on the well completion diagram for LMW-5 in Appendix E.

- The screen section of LMW-7 was set in the open mine workings of the Landsburg seam. The void area associated with the mine workings precluded the setting of a filter pack. A "catch" system similar to LMW-5 was constructed for completion of the well. Sand was tremied down the annulus and used to form the bridge on top of the catch. Bentonite chip were not used to form the bridge, because the angle of LMW-7 would not permit the bentonite chips to be passed down the annulus. Once a suitable base of sand was established, the remainder of the annulus was grouted as described for LMW-5. During pulling of the 8-inch steel outer casing, the steel casing became stuck and could not be completely removed from the borehole. A backhoe was used to remove soil from around the 8-inch casing to a depth of 18 feet. The casing was then cut at this depth and the soil was backfilled around the casing. The annulus was then grouted to the surface and the 18-foot section of 8-inch casing was removed.

All monitoring wells were completed with protective anodized aluminum well monuments having lockable lids. Three concrete filled steel posts ("bumper posts") were placed in a triangular array around each protective monument to provide additional protection for the monument. A domed concrete pad was constructed around the base of the monument to divert water runoff away from the well.

The additional borehole (LMW-1A) was completed with a 2-inch schedule 40 PVC screen (20 feet in length) and casing. A 4-inch PVC, with an 8-inch packer on the bottom end, was inserted into the borehole over the 2-inch casing to a depth of 22 feet below the ground surface. The 8-inch packer served as a catch for the bentonite chips which were used to seal the annulus to the surface. The well was completed with a steel monument with a lockable lid. LMW-1A was used for monitoring hydrogeologic conditions only. Groundwater samples were not taken from this well.

Following installation of the groundwater monitoring wells, and after adequate time had elapsed for the grout to harden, the monitoring wells were developed by air lifting water from the well. The air rotary drilling rig was used to air lift and develop each well until relatively silt-free water flowed from the well. The purpose of this initial development was to remove as much of the silt and sand as possible from the well prior to the installation of the dedicated sampling pump system.

The drill cuttings produced during drilling operations were collected in labeled 55-gallon Department of Transportation approved drums. The drums were then transported to a storage area inside the fenced portion of the mine site. At the completion of the drilling process composite samples of captured cuttings from each borehole were obtained and analyzed for volatile organics (EPA Method 8240), semivolatile organics (EPA Method 8270), PCBs and pesticides (EPA Method 8080) and metals (EPA Method 6010) analysis. A summary of analytical results for these samples is listed in Appendix C.

There were no organic compounds detected above MTCA Method B cleanup values in any of the composite 55-gallon drum samples. Based on these analytical results and after receiving approval from Ecology, the collected soil cuttings were disposed of into the Landsburg trench. After being emptied, the 55-gallon drums were pressure washed and delivered to a recycling facility. Information concerning disposal of the drill cuttings is provided in Pancoast (1994a).

Large volumes of formation water encountered during drilling at LMW-2, LMW-3, LMW-4, and LMW-5 were collected and stored in large (4,000, 6,500 and 21,000 gallon) Baker tanks. Groundwater produced during the development process was also collected in the Baker tanks, and in 55-gallon drums for LMW-1. Characterization of the captured groundwater was determined from the results of groundwater sample analysis during the first monitoring period.

After receipt, validation, and evaluation of the groundwater sample analysis and after receiving approval from Ecology, the groundwater stored in the Baker tanks in the vicinity of LMW-2 and LMW-4 (north end of the trench) was pumped from the tanks into the Landsburg trench at a location approximately 150 feet southwest of portal #2 (Figure 2-14). The water stored in Baker tanks at the LMW-3 and LMW-5 site was pumped to an infiltration area approximately 300 feet southeast of LMW-3 (Figure 2-15). Formation water collected in 55-gallon drums was disposed of in conjunction with the disposal of drill cuttings as described above. Information regarding the disposal of groundwater produced during well construction and development is presented in Pancoast (1994b).

Disposal of groundwater stored in Baker tanks was used as an opportunity to collect additional hydrogeologic data. Electronic data loggers were used to monitor LMW-1, LMW-2, LMW-3, and LMW-4 for changes in water level during draining of the Baker tanks and for a period of time following disposal of the water. Results of the hydrologic monitoring are presented in Appendix B and discussed in Section 3.6.3.3.

2.7.3 Inclinometer Surveys

The inclination of monitoring wells LMW-1, LMW-4 and LMW-7 was measured by Golder geophysics personnel using an Applied Physics Systems Model 544 Miniature Angular Orientation Sensor. This system contains both a 3 axis accelerometer and a 3 axis fluxgate magnetometer, as well as two temperature probes for calibration purposes. Roll and vertical inclination angles are determined from the accelerometer unit. After these values are known, the magnetometer unit is used to determine the horizontal azimuth angle. The Model 544 is battery operated and contains a microprocessor that interfaces with a field computer for data display and storage. The sensor is contained in a 3-inch diameter downhole probe that is connected to the surface via a cable marked at 10-ft intervals.

LMW-4 was logged prior to well installation while the other two boreholes were logged after well installation. LMW-4 and -7 were logged to determine the true dip of the boreholes, which were drilled at an intended 20 degree inclination. LMW-1 was logged to determine any deviation from the intended vertical orientation. The inclination of each of the three wells was measured at 10-ft intervals.

The inclination of LMW-1 ranges from about 1 to 4.5 degrees. It is approximately 9 ft off of vertical at the bottom of the 177-ft deep hole. The inclination of LMW-4 ranges from about 20 to 30 degrees. The bottom of the borehole is approximately 20 ft off from the intended 20 degree inclination. The inclination of LMW-7 ranges from about 17 to 23 degrees. The bottom of the borehole is less than 3 ft off from the intended 20 degree inclination. The deviations of these boreholes from their intended inclinations are considered normal under typical drilling conditions and operations.

2.7.4 Hydraulic Testing

A thorough knowledge of hydraulic parameters at the Landsburg Mine site in general, and the Rogers Seam in particular, is essential for the characterization of site hydrogeology. Aquifer hydraulic conductivities were estimated at monitoring wells LMW-1, LMW-2, LMW-3, LMW-4, and LMW-5 primarily by performing piezometer, or slug, tests on each well. Pumping tests (drawdown/recovery tests) were also attempted at each well pair. Additional hydraulic data were obtained by monitoring water levels in selected wells during the Baker tank water disposal. A discussion of hydraulic testing procedures is provided below. Presentation of results are provided in Section 3.6. Detailed discussion of the data analysis procedures are provided in Appendix F.

2.7.4.1 Slug Testing

Piezometer tests, also referred to as slug tests, are a method commonly utilized to determine in-situ hydraulic parameters at a single piezometer or monitoring well. Slug tests are initiated by inducing an instantaneous change in water level by adding, displacing, or removing, a known volume, or "slug" of water. Water levels within the well are monitored over time as they recover to pre-test conditions. A variety of data analysis methods are available to account for varying hydrogeologic conditions. Slug tests provide a simple, cost-effective method of determining aquifer parameters. However, the accuracy of the tests are dependent upon the design and construction of the tested well and possible disrupting effects of the borehole drilling process. Therefore, the aquifer parameters determined by the analysis of slug test data is generally considered to be accurate only to within an order of magnitude of actual in-situ conditions.

Slug tests were performed at the Landsburg Mine site in monitoring wells LMW-1, LMW-2, LMW-3, LMW-4, and LMW-5 on March 4, 1994. All testing was performed by Golder personnel utilizing procedures outlined in Golder Technical Procedure TP-1.2-17 "Rising Head Slug Test" and the QAPP. Water levels were monitored in each well with a down-hole pressure transducer and an automatic data recorder positioned at the top of the well (the pressure transducer and the single channel Aquistar DL-1 data recorder are products of Instrumentation Northwest, Inc., of Redmond, Washington). The data recorder was programmed to acquire and record data at scan intervals ranging from one second to ten minutes during the test interval. The scanning sequence was initiated as the slug was introduced to, or removed from, the well. Following the test, the data recorder was accessed with a portable personal computer and the data was downloaded to a 3.5-inch floppy disk. The data files were then imported into an Excel format file for analysis.

The slug utilized for each of the tests consisted of a five-foot section of two-inch diameter Schedule 40 PVC pipe filled with sand and capped at both ends with PVC slip caps. The slip caps were held in place with stainless steel set screws. The slug was raised and lowered with a section of nylon rope tied to a stainless steel eye bolt installed at one end of the slug. In order to prevent cross-contamination between wells, the slug underwent a decontamination procedure and a new section of rope was used for each test. When fully submerged in the well. the slug displaces approximately 0.11 ft^3, or 0.82 gallons of water.

Two slug tests were conducted in well LMW-5, both of which involved inserting the slug into the water and inducing a water level rise. After the first test, an attempt was made to run another test after removing the slug from the water and inducing a drop in water level. However, the transducer cable became tangled with the slug cord as the slug was being removed. This displaced the transducer, making a determination of its position, at any given time relative to the initial water table, impossible. After allowing enough time for the water table to fully recover to pre-test levels, the second slug insertion test was conducted.

In order to prevent the cord tangling problems experienced during the LMW-5 tests while testing at well LMW-3, the transducer cable was attached directly to the slug body with PVC cable-ties. Just prior to initiating the test, the slug and transducer were lowered into the well and held in a position with the slug resting a few inches above the water table. In order to induce the water level rise, the slug and transducer were simultaneously dropped into the well and secured at a level that resulted in the slug being completely submerged at all times during the test. The initial LMW-3 test was terminated when it was discovered that the water level had dropped below the top of the slug just prior to reaching full recovery. This indicated that the transducer had not been lowered enough when the test was started. Prior to starting Test 2, the slug and transducer were lowered to ensure that the slug would remain below the static water level until the well had fully recovered. Test 2 was initiated by quickly raising the slug and transducer (inducing a water level drop) and securing it at a level that ensured the slug was well above the static water level, but maintained the transducer below the current water level and well below the static water level. Water level monitoring continued until the water level had recovered to the pre-testing level.

Three individual slug tests were conducted in monitoring well LMW-2. Testing procedures were similar to those used in well LMW-5 with the separate transducer and slug assemblies. The relatively shallow water table did not require the slug to be raised and lowered to depths as great as those needed in LMW-3 and LMW-5. This minimized problems with tangling of the slug cord and transducer cable. Test 1 was initiated by lowering and submerging the slug. When water levels had fully recovered, Test 2 was initiated by quickly removing the slug, inducing a water level drop. Test 3 was initiated by pouring approximately 2.25 gallons of distilled/deionized water. Water levels recovered relatively quickly during all three testing periods. The three LMW-2 slug tests were conducted immediately following well development activities at monitoring well LMW-4 and just prior to similar activity in LMW-2. It was reported that LMW-4 remained at the static water level throughout the development process.

Two individual slug tests were performed in monitoring well LMW-4. Testing procedures were similar to those used at wells LMW-2 and LMW-5. Test 1 was initiated by lowering and submerging the slug, while Test 2 consisted of raising the slug out of the water and monitoring the water level recovery. It should be noted that the LMW-4 testing was conducted while well LMW-2 was being developed. Development pumping rates at LMW-2 were low (approximately 5 gallons per minute) and did not appear to have a discernible effect on water levels at LMW-4.

One slug test was conducted in monitoring well LMW-1. Well LMW-1 was drilled and completed within the sandstone bedrock which lies on either side of the Rogers coal seam. Because the sandstone was suspected to have a relatively low hydraulic conductivity, the slug test was conducted over an approximately 12 hour time period. Due to the depth to water in LMW-1 (approximately 140 feet below ground surface) the transducer cable was again attached to the slug body to prevent tangling of the cable and the slug cord. After lowering the transducer into the water and allowing for full recovery to static conditions, the test was initiated by quickly lowering and submerging the slug and transducer and securing the cables at the surface. The test was allowed to continue overnight.

2.7.4.2 Pump Testing

Pumping tests were conducted at each of the well pairs located at the north and south ends of the Rogers Seam. In each instance, groundwater was pumped at a constant rate from the deeper of the two wells while water levels were monitored in both the deep and shallow wells in the well pair. The Grundfos sampling pumps installed in each well (described below in Section 2.7.5) were utilized for the pumping tests. During each test a constant flow rate of approximately six gallons per minute (gpm) was maintained for the duration of the test. Water was discharged directly into on-site Baker tanks for storage. Water levels were monitored in each well with a down-hole pressure transducer and an automatic data recorder positioned at the top of the well. Test 1 consisted of pumping from well LMW-4 and monitoring water levels in LMW-2. Test 2 consisted of pumping from well LMW-5 and monitoring water levels in LMW-3. Test 1 was conducted over a 253 minute period, while Test 2 was completed in approximately 178 minutes. Both pump tests were conducted on March 24, 1994.

2.7.5 Installation of Dedicated Sampling Pumps

All groundwater monitoring wells were completed with permanent dedicated sampling pump systems. The Redi-Flo2 stainless steel submersible pump (manufactured by Grundfos), with teflon-lined polyethylene discharge hose and sealed motor lead wires, was selected for installation because of their reliability and proven performance in other monitoring well situations. The pumps purge groundwater under positive pressure. Production rates range from a slight trickle, which is preferred for sampling, to approximately 4 to 5 gpm for purging. The groundwater samples only contact stainless steel and teflon materials in the pump assembly and production casing. The pumps installed in wells LMW-3, LMW-4, LMW-5, and LMW-6 are equipped with a viton packer assembly approximately 10 feet above the pump unit. The packer assembly is inflated with nitrogen sealing off the water column above the packer thus significantly reducing the volume of purge water required during sampling.

2.8 Task 10 - Groundwater Sampling and Analysis

As discussed in GAI (1992b), the groundwater pathway represents the major potential pathway for contaminant migration and potential exposure from the Landsburg Mine site. In order to assess the extent or presence of any groundwater contamination at the site or in groundwater wells contiguous to the site, the 14 wells selected under Task 5, and the seven monitoring wells installed under Task 9, were sampled in accordance with the Work Plan (Golder 1992a).

2.8.1 Private Well Groundwater Sampling

Sampling and analysis was performed on a quarterly basis for the selected 13 private wells and the City of Kent-Clark Springs facility. A total of four rounds have been completed. The first quarterly sampling was conducted in May 1994. Subsequent sampling periods occurred in August 1994, December 1994 and March 1995. The fourth sampling round was conducted at a reduced list of private wells, consisting of 7 of the 14 wells, as approved by Ecology. These wells included PW-2, -3, -4, -9, -10, -12, and -13. Table 2-2 provides a summary of private well sampling activities. The overall objective of the off-site groundwater sampling is to provide sufficient information for WDOH and Ecology to evaluate the existing groundwater quality conditions in drinking water wells around the site. These data will also be used to assess the hydrogeologic conditions of the Study Area.

Groundwater samples collected from the private wells were analyzed for Target Analyte List (TAL) metals, cyanide, wet chemistry/anions, volatile organics (EPA Method 524.2), semivolatile organics (EPA Method 8270), pesticides and PCBs (EPA Method 8080 first, second and fourth quarters, EPA Method 508 third quarter). General water quality parameters and drinking water standards were also analyzed. Due to low turbidity levels, all analyses were conducted on un-filtered samples. Samples for metals analysis were field acidified.

In addition to the analytes obtained through the above referenced EPA analytical methods, Ecology and WDOH recommended analyzing private well water samples using EPA Method 525 for lower detection limits on specific organic compounds and to detect additional pesticide compounds. Private well samples were analyzed using EPA Method 525 during the first and third monitoring periods. Analysis using EPA Methods 524.2, 508 and 525 were conducted by Inland Environmental Laboratory in Spokane, Washington, a WDOH certified laboratory. All other analyses were conducted by Analytical Resources Inc., in Seattle, Washington. Table 5-4 provides a summary of analytes detected in groundwater samples from private wells. A complete summary of all analytes tested for and results is provided in Appendix C.

Each sampling event included the following general activities:

- observation of the general condition of the well, well seals, monuments and protective covers, well houses, etc.

- measurement of static water level from a surveyed reference point,

- well purging to insure sample representativeness,

- measurement of field parameters pH, electrical conductance, temperature and dissolved oxygen periodically during purging, and

- collection of representative groundwater samples in appropriate containers.

Each of these activities were subject to controls and strict QA protocols and procedures specified in the relevant technical procedures referenced in the QAPP. Water levels were taken according to the specifications of procedure TP-1.4-6 “Water Level Measurements”. Sample collection and handling was performed as described in procedure TP-1.2-20 “Collection of Groundwater Quality Samples”. All instruments used for field analysis were calibrated in accordance with procedure P-12.0-1, “Calibration and Maintenance of Measuring and Test Equipment”. Chain of custody was maintained in accordance with the procedure TP-1.2-23, “Sample Handling and Chain of Custody”.

Static water levels were measured at each well prior to the initiation of any other activities. An electric well sounder was used for all manual water level measurements. The sounder was cleaned before and after each use with organic free distilled/deionized water. Water levels were measured from the top of the well casing and were recorded to the nearest 0.01 feet.

Purging consisted of the removal of a minimum of three well volumes from a well prior to sample collection. Wells with extremely low production rates (PW-6, PW-7, PW-8, and PW-15) would pump dry prior to purging the minimum three well volumes goal. The low-producing wells were purged until dry, allowed sufficient time to recover, and were then immediately sampled. Private wells were purged utilizing the well's existing pump. Private well PW-10 utilizes a jet pump, the City of Kent-Clark Springs uses a gravity collection system, and all other private wells sampled are equipped with submersible pumps. During purging, field parameters pH, electrical conductivity and temperature were periodically measured. All field parameter measurements and purge volumes collected were recorded on Sample Integrity Data Sheets for maintenance in the project file.

Samples were collected from faucets located at the well head or as close to the well head as possible. To ensure that samples collected were representative of groundwater from the well and not of water within the well system, no samples were collected from faucets located "after" holding tanks or pressure tanks. Samples collected at the City of Kent-Clark Springs facility were obtained from a brass fitting connected to the 18-inch mainline in the surge room.

Samples were collected in properly cleaned bottles of appropriate volume and type. Samples were preserved as required. After filling, the bottles were immediately sealed, labeled and placed in a cooler maintained at 4^{o} C. Samples were transported to the analytical facilities under formal chain of custody documentation and in sufficient time to conduct the requested analyses within the specified holding times.

Documentation for sampling included bottle labels, completion of Sample Integrity Data Sheets, Field Report Forms and Chain of Custody Records. Sample coolers were secured with chain of custody seals. The Field Report Form and Sample Integrity Data Sheet were used to document daily site activities and sample collection.

2.8.2 Monitoring Well Groundwater Sampling

Sampling and analysis has been performed on a quarterly basis for the seven monitoring wells installed under Task 9. Four sampling rounds have been completed. The first quarterly sampling was conducted in April 1994. Subsequent sampling periods occurred in August 1994, December 1994 and March 1995. Table 2-2 provides a summary of monitoring well sampling activities.

Groundwater samples collected from the monitoring wells were analyzed for TAL metals, cyanide, wet chemistry/anions, volatile organic compounds (EPA Method 524.2), semi-volatile compounds (EPA Method 8270), pesticides/PCBs (EPA Method 8080 first, second and fourth quarters, EPA Method 508 third quarter) and other general water quality parameters. All analyses, with the exception of LMW-1 metals, were conducted on un-filtered samples. LMW-1 metals sample was filtered through a 0.45 *u*m in-line filter. Samples for metals were field acidified.

In addition to the analytes obtained through the above referenced EPA analytical methods, Ecology and WDOH recommended analyzing monitoring well water samples using EPA Methods 525, 504, 515.1 and 531.1 for lower detection limits on specific organic compounds and to detect additional pesticide compounds. All monitoring well samples were analyzed using EPA Methods 525, 504, 515.1 and 531.1 during the first and third monitoring periods. Analysis by Method 504 was also conducted during the second round. Analysis using referenced methods 524.2, 504, 508, 525, 515.1 and 531.1 were conducted by Inland Environmental Laboratory in Spokane, Washington, a WDOH certified laboratory. All other analyses were conducted by Analytical Resources Inc., in Seattle, Washington. Table 5-3 provides a summary of all analytes detected in groundwater samples from monitoring wells. A complete summary of all analytes tested for and results is provided in Appendix C.

General monitoring well sampling procedures parallel those described above for the private well groundwater sampling. Sampling activities were subject to controls and strict QA protocols and procedures specified in the above listed technical procedures.

Static water levels were measured at each well prior to the initiation of any other activities. An electric well sounder was used for all manual water level measurements. The sounder was cleaned before and after each use. Water levels were measured from the elevation survey mark and were recorded to the nearest 0.01 feet. All recordings, dates, times and well designations were recorded on Water Level Readings Forms and Sample Integrity Data Sheets for maintenance in the project file.

As detailed for the private wells, a minimum of three well volumes was purged from the monitoring wells prior to sample collection. All monitoring wells were purged with the dedicated sampling pumps described in Section 2.7.5. During purging, field parameters pH, electrical conductivity, turbidity and temperature were periodically measured. All field parameter measurements and purge volumes were recorded on Sample Integrity Data Sheets. During purging of wells LMW-3, LMW-4, LMW-5, and LMW-6, the packer was inflated prior to groundwater removal, hence one volume of well water represented the entrained water below the packer. As a result of the low yielding nature of LMW-1, purging of three well volumes was not possible. LMW-1 was purged until dry, allowed sufficient time to recover, and then sampled.

Purge water produced during the first two sampling rounds was collected in the Baker Tanks and in 55-gallon drums for LMW-1 and LMW-7. As described in Section 2.7.2, final disposal of the collected groundwater was conducted within the confines of the mine site. Purge water produced during the third and fourth quarter sampling was discharged to the surrounding soil.

Samples were collected in properly cleaned bottles of appropriate volume and type. Samples were preserved as required. After filling, the bottles were immediately sealed, labeled and placed in a cooler maintained at 4^{o} C. Samples were transported to the analytical facilities under formal chain of custody documentation and in sufficient time to conduct the requested analyses within the specified holding times.

Documentation for sampling included bottle labels, completion of Sample Integrity Data Sheets, Field Report Forms and Chain of Custody Records. Sample coolers were secured with chain of custody seals. The Field Report Form and Sample Integrity Data Sheet were used to document daily site activities and sample collection.

2.9 Task 11 - Topographic Survey and Geodetic Control

Performance of the Landsburg Mine RI/FS requires detailed and accurate maps for reporting and presentation purposes, and for accurate evaluations of trench volumes, site surface water drainage patterns and other site characteristics. An accurate system of horizontal and vertical geodetic control has been established for the mine site. All elevations have been established to United States Geological Survey (USGS) datum of mean sea level. Horizontal surveys reference Washington State Plane Coordinates in accordance with WAC 173-340-840(4)(e) and (f). Site topographic and geodetic control has been established through a combination of aerial photogrammetry and site geodetic surveys.

DeGross Aerial Mapping of Bothell, Washington was contracted to perform aerial photogrammetry and topographic base map preparation of the Landsburg Mine site area. Figure 2-16 provides a composite copy of the aerial photos taken of the site area. The aim of the survey was to develop a topographic base map of the site vicinity along the Rogers trench which could be utilized in development of detailed plan view site maps. The base map was generated from stereoscopic images obtained in an aerial fly-over.

The base map was prepared to 2 foot contours with a scale of 1 inch = 100 feet. The topographic base map was developed in an AutoCad computer format for use in site plan development and preparation of report figures (e.g., Figure 2-3).

Cramer & Niclas, Inc., of Kent, Washington was contracted to set up photogrametry reference points and perform geodetic (x, y, and z) surveys of all sampling locations, private wells and other miscellaneous features. The survey was of Third Order Accuracy and Precision. Surveyed locations were entered into the AutoCad program and incorporated into the topographic base map. Surveyed well elevation data are shown in Table 2-4.

2.10 Task 12 - Ecological and Social Data

In order to assess the potential impacts of the Landsburg Mine site on the surrounding environment, data pertaining to certain relevant ecological and social characteristics were collected. Information collected include meteorologic and hydrologic data, data concerning the possible presence of endangered or threatened species and sensitive habitat, and current land and water use. Collection of this information is subdivided into the following activities:

- Meteorology
- Surface Water Flow (Cedar River)
- Land Use (Zoning and Sensitive Areas)

- Endangered Species
- Priority Habitats and Species

Information for each of these areas was obtained over the established Study Area. The Study Area is defined as outlined in Figure 1-2.

2.10.1 Meteorology

A meteorologic station operated by the City of Seattle Water Department is located on the Cedar River at the City's water intake facility (Figure 2-2). The station represents the closest official weather monitoring point to the Landsburg Mine and is therefore expected to be representative of conditions at the site. Monthly summary reports for the station have been obtained from the City of Seattle for the time period of April 1992 to January 1995. In addition, monthly precipitation and temperature data for the station have been obtained for the period 1931-1993 (Hydrosphere Data Products 1993a). Regional and site meteorological characteristics are discussed in Section 3.5.

2.10.2 Surface Water Flow Data (Cedar River)

Two flow gauging stations are located on the Cedar River in the vicinity of Seattle's water intake facility. One is approximately 1 mile upstream of the water intake, and the second is immediately downstream of the diversion. Flow data observations taken from these stations are available in Hydrophere Data Products (1993b). Included in these reports are monthly mean, minima and maxima flow rates based on all years that data are available.

Additional monitoring of the Cedar River was obtained through periodic measurements taken of the rivers surface elevation. Measurements were taken from a surveyed point on the bridge crossing the Cedar River on Landsburg Road SE. Cedar River elevation measurements have been graphed and are included in Appendix B. Surface water characteristics are discussed in Section 3.5.

2.10.3 Land Use

Relevant maps pertaining to the current zoning of the Study Area, as mandated by the King County Zoning Ordinance Title 21, were reviewed at the King County Department of Development and Environmental Services, Land Use Services Division in Bellevue, Washington. Additional maps were obtained and reviewed to identify the presence of sensitive areas, as defined by the Sensitive Areas Ordinance (King County Ordinance 9614), within the site area. Section 3.7.1 describes the current zoning of the Study Area. Sensitive areas are described in Section 3.7.3.3.

2.10.4 Endangered Species

This activity consisted of the collection of existing information on sightings of endangered or threatened species in the Study Area. Information was obtained from the United States Department of Interior Fish and Wildlife Service in Olympia, Washington and the Washington State Department of Wildlife. Information collected is discussed in Section 3.7.3.1.

2.10.5 Priority Habitat and Species

This activity consisted of the collection of existing information from the Washington State Department of Wildlife's (WDW) Fisheries, Habitat and Wildlife Management Division. Priority Habitat & Species and Natural Wildlife Heritage Data maps (PHS/HRTG), produced by WDW, were obtained for the Study Area. In addition, information on potential sensitive habitats (i.e. wetlands) located within the site area were documented during site walk overs conducted throughout the RI. Section 3.7.3.2 contains a discussion of priority habitats and species within the Study Area.

2.11 Task 13 - Geologic Reconnaissance

The purpose of this task was to further characterize the geologic setting of the Landsburg Mine area by collecting general information on local geologic features and to aid in the precise locating of the exploratory boreholes/monitoring wells. The geologic information was used to further develop the overall conceptual understanding of geologic conditions and features, and their importance to groundwater flow, contaminant migration, and the geological engineering aspects of site remedial actions.

The geologic reconnaissance activities consisted of geologic mapping of surface geologic features in the mine area and of the subsurface in the immediate vicinity of the trench. As such, two activities were completed for this task:

- Site Walk Over and Geologic Mapping
- Backhoe Trenching Perpendicular to Rogers Seam for Geologic Definition

2.11.1 Site Walk Over and Geologic Mapping

This activity consisted of several site walk overs and geologic reconnaissance activities by GAI personnel conducted throughout the field RI process. The objectives of this activity were as follows:

- To verify the surficial geologic conditions of the site, note general geologic features, map the site surface water drainage patterns, and locate any springs (in both wet and dry seasons) that may be present in the site vicinity,

- observe the surface water discharge characteristics of portals #2 and #3 in order to evaluate the optimum method to be used in surface water sample collection and flow rate monitoring at the two portals. This served as input for Task 6 as described in Section 2.4.

- Locate Frasier and Landsburg seam portals for input to Tasks 6 and 7. The portals were evaluated to assess their suitability for background surface soil sampling and surface water sampling.

- To locate any potential wetlands or other potentially sensitive habitat that may be present in the site vicinity. Information regarding wetlands served as input to Task 12 - Ecological and Social Data.

- Locating the outcrop or subcrop of the coal seams for placement of monitoring wells in Task 9 - Drilling and Well Installation.

All relevant features identified as part of the surveys were marked in the field and included in the site geodetic survey. Information obtained during the surveys was utilized in the completion of various tasks during the RI process and is described in Chapter 3.

2.11.2 Activity 13b - Backhoe Trenching Perpendicular to Rogers Seam for Geologic Definition

The purpose of this activity was to collect data related to the near-field geologic setting of the mine trench area. The activity included geologic mapping, by a qualified geologist, of three shallow trenches dug perpendicular to the Rogers Seam. The primary aim of the trenching was to define the nature of bedding within the bedrock materials on either side of the Rogers Seam, including the stratigraphic sequence, thickness and orientation of units, structure and moisture. Information regarding the stratigraphy of bedrock materials adjacent to the trench is important in understanding the potential for chemical migration laterally away from the mine. Some additional trenching was conducted to assist in the location and placement of monitoring well drilling locations.

Trenches were dug at three locations at the mine site with a backhoe. Two of the trenches were dug on the east side and one was dug on the west side of the subsidence trench. Figure 2-5 shows the three trench locations. The trenches extend away from the mine subsidence trench in a perpendicular fashion and were dug to a maximum depth of 4 feet. Important structural and stratigraphic features were recorded on field log records. The recorded trench stratigraphic logs are included in Appendix E.

A composite sample was obtained of the excavated soils from each pit and was analyzed for TAL and TCL constituents. Sampling was conducted following the procedures and requirements described in Section 2.5 - Surface Soil Sampling. Results of the soil sampling and analysis are provided in Table 5-8 and Appendix C.

Four additional trenches were dug in the revised LMW-2 and LMW-4 drilling area to locate the northern extent of the Rogers coal seam outcrop near the Summit-Landsburg Road. One long trench (approximately 40 feet) was excavated to the west of the estimated coal seam, and three shorter (approximately 10 feet) trenches were excavated to the east. No *in situ* coal was encountered in any of the excavations. However, evidence of a filled depression (based on stratigraphy encountered and nature of the fill) was noted near the previously estimated outcrop location. The Rogers Seam, in the vicinity of LMW-2 and -4, had been surfaced mined to a depth of approximately 25 feet. The information obtained from these excavations was then used in the surface projection of the Rogers Seam, and subsequently in the locating of boreholes LMW-2 and LMW-4.

All work under this activity was performed in compliance with GAI procedure TP-1.3-1, "Technical Procedure for Geologic Mapping of Soils Exposed in Test Pits", as discussed in the QAPP.